JOHNSTON CREEK

EDUKIT

EROSION BY WATER AND ICE

TEACHER'S GUIDE

ISBN 0-919685-12-9

The Johnston Creek Edukit is available on slide/tape from your local Field Service Specialist, and on video cassette from the Access Media Resource Centre.

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WHERE TO FIND WHAT . . .

. . . table of contents.

WHAT IT'S ALL ABOUT . . .

The Johnson Creek Edukit tells the story of landscape sculpturing by water and ice erosion in the Johnson Creek area of the Rocky Mountains in Banff National Park.

The Johnston Creek Edukit is a co-production of Parks Canada and ACCESS Alberta. It is compatible with both the objectives of Parks Canada and the school curricula in the province of Alberta.

Parks Canada's objective for national parks is:

> **to protect for all time representative natural areas of Canadian significance in a system of national parks, and to encourage public understanding, appreciation, and enjoyment of this natural heritage for future generations.**

The Edukit was produced to tell the story of Johnston Creek to Alberta students.

"By the use of interdisciplinary enquiry, students are actively encouraged to develop process skills and communicate them in a creative and imaginative way. This exciting approach stimulates the students' interest in science and allows them to discover the mechanics of erosion, glaciation, and ecology within the context of the Johnston Creek story. The Edukit can provide a suitable climax to the Grade Eight science curriculum. It is suitable for a project in the Science Eleven program and could be used with Biology Twenty students. Some use could also be made of the Edukit at the Grade Six level in the proposed elementary science curriculum."

Patricia McWilliams
Consultant (Science)
Alberta Education

To discover the interests and needs of Alberta teachers, a questionnaire was distributed to schools in the province. The questionnaire and its responses are included in the kit for your reference. Many of the suggestions were incorporated into the design of the Edukit. The responses indicated an interest in both on-site and in-classroom components. Study aids have been prepared for classroom instruction and a field guide for on-site use. The kit has been designed with flexibility so that it may be adapted to the particular needs of each teacher.

The Natural and Human History of Banff National Park is included in the kit in response to the widespread interest expressed in this area.

THEME, GOALS, AND OBJECTIVES

THE PRIMARY THEME of the Johnston Creek Edukit is the erosive power of running water and how this power has produced the spectacular features evident in the area. The major concepts described include the following:

(a) the process of mountain building
(b) the effects of water and glaciation on the landscape of Johnston Canyon
(c) mechanical and chemical erosion
(d) the role of national parks in preserving such areas.

The Johnston Creek Edukit strives to achieve the following:

1 LEARNER GOALS

As a result of using the Edukit, learners will become aware of:

(a) the erosive force of water and how water has sculptured the landscape of Johnston Canyon.
(b) Johnston Creek is but one focal point in the Rocky Mountains which illustrates these processes.
(c) other interpretive opportunities that exist in the Johnston Creek area.
(d) the significance and importance of the heritage values protected in national parks.

2 LEARNER OBJECTIVES

As a result of using the Edukit, learners will be able to:

(a) understand how the action of Johnston Creek is producing the landscape features in Johnston Canyon.
(b) understand the story of Johnston Creek before, during, and after glaciation.
(c) explain the significance of the Ink Pots to the overall story of Johnston Creek.
(d) develop an interest in the landscape sculpturing processes.

HERE'S WHAT YOU GET . . .

. . . contents of the kit

PRINT COMPONENT

- Johnston Creek Edukit: Erosion by Water and Ice Teacher's Guide
- Johnston Canyon: What to Do When You Get There: A Teacher's Guide for a Field Trip
- Program Transcripts
- The Geology of Banff National Park
- The Natural and Human History of Banff National Park
- poster
- results from "Needs and Interests" questionnaire distributed to Alberta teachers
- operating instructions for video cassette and slide/tape programs.

AUDIO-VISUAL COMPONENT

Slide/tape programs: the kit includes four carousels of slides with four audio cassettes.

Program 1: The Power of Running Water
Program 2: Canyon Formation
Program 3: Features of Johnston Canyon
Program 4: Johnston Creek within the Setting of Banff National Park

Video cassette: the four slide/tape programs transferred to one sixty-minute cassette.

HOW TO USE IT:

suggestions for lesson formats, including questions and answers for each program

Your Edukit contains both slide/tape programs and a video cassette. The video cassette contains all four slide/tape programs and is approximately sixty minutes in length. It is easy to use but can only be viewed on a standard television screen. It is recommended that the video cassette be utilized as a condensed information package to motivate students prior to a field trip.

The major instructional medium for classroom use is the slide/tape program. Each slide/tape program is designed as a separate lesson and is about ten minutes in length. A format for each lesson utilizing the slide/tape program could include:

1 . . . **a sneak preview**
The transcript of each program is included in the Edukit to enable you to review program content before presentation. Key words identifying major program concepts are indicated by boldface type in the transcripts.

2 . . . **lights, camera, action**
You could now present the slide/tape program to your class. Instructions for operating the slide projector and cassette recorder are included in the Edukit.

3 . . . **questions, anyone?**
In order to review the slide/tape programs with your class, three types of questions have been prepared for each program:

- subject, questions, focussing on content recall
- questions incorporating science-process skills
- activity-oriented questions, offering a lighter, interactive approach.

Each type of question covers all major concepts in that program. Select whatever types of questions you prefer and xerox them, if you wish. Answers to the questions are included at the back.

4 . . . **and now for a short quiz.**
A review with answers for all four programs is included at the back. The review could also be xeroxed and distributed to your students.

QUESTIONS INCORPORATING SCIENCE-PROCESS SKILLS - APPROACH

Following are questions incorporating science-process skills. After answering a question, list the science-process skill(s) inherent in that question. The skills given are suggestions only. Different individuals may utilize different skills, but they should be able to explain which skills were used and why.

SUMMARY OF PROCESSES IN SCIENTIFIC INQUIRY

INITIATION

1 Problem identification and definition

2 Seeking background information

3 Predicting

4 Hypothesizing

5 Designing collection of data through field work and/or experimentation.

COLLECTION OF DATA

6 Procedure

7 Observing and observations.

PROCESSING DATA

8 Organizing the data

9 Representing the data graphically

10 Treating the data mathematically.

CONCEPTUALIZATION OF DATA

11 Interpreting the data

12 Formulating operational definitions

13 Expressing data in the form of a mathematical relationship

14 Incorporation of the new discovery into the existing theory (developing a "mental model").

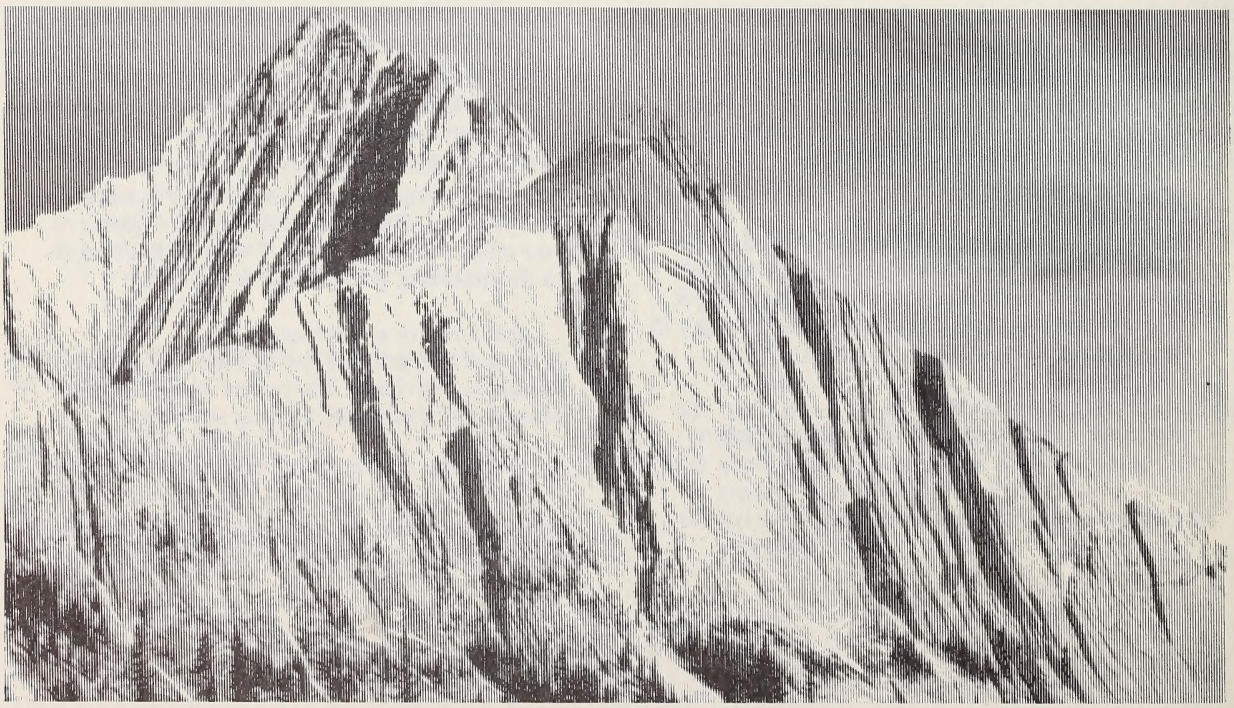
OPENENDEDNESS

15 Seeking further evidence

16 Identifying new problems for investigation

17 Applying the discovered knowledge.

Nay, M.A. "A Process Approach to Teaching Science", *Science Education*, 55:pp. 197 - 207, 1971.



Subject questions

1 What is the major story portrayed by the Johnston Creek Edukit?

2 Where is the Johnston Creek area located?

3 What is the source of Johnston Creek?

4 Of what type of rock are the surrounding mountains composed?

5 Explain how this rock was formed.

6 What name is given to rock composed of:
(a) sand?
(b) silt?
(c) marine animals?

7 Explain why the Rocky Mountains, rock which once lay beneath an ancient sea, now tower high above the plains.

8 Why are the surrounding banks of Johnston Creek higher and steeper in some places than in others?

9 Was the upper valley of the Johnston Creek area originally V-shaped or U-shaped? How was it formed?

10 What evidence suggests that glaciers once existed in the upper valley? How did they affect the valley's shape?

11 Johnston Creek once emptied into the Bow River, four kilometres east of its present course. Suggest two possibilities that may have caused this dramatic change in direction.

12 What was the result of Johnston Creek's change of direction?

13 When were the lower canyons sculptured?

Science – process questions

1 **Background information**
The bedrock of Johnston Canyon consists of sedimentary rock. Marine fossils and ripple marks have been discovered in sedimentary rock throughout the Canadian Rockies. These rock layers have been arched, folded, and thrust up like huge building blocks.

(a) Recall the layered condition of the many rock faces along the path of Johnston Creek. Using the knowledge of how a layer cake is made, suggest an explanation for the sedimentation of the bedrock.

(b) Utilizing the observation regarding fossils and ripple marks, indicate the probable conditions under which these sediments were deposited.

(c) Considering the above data, formulate a theory to explain why rock from beneath an ancient sea now towers above the plains.

(d) Design a model to illustrate the following: deposition of sediments; compression into rock; and thrusting of rock layers high into the air. You might use layers of plasticene covering a "sea-bottom" of wax paper.

2 **Background information**
Johnston Creek originates high in Pulsatilla Pass, where runoff from rain, melting ice and snow accumulates. Drawn by the pull of gravity, Johnston Creek traces a path to the Bow River. The Johnston Creek area is U-shaped at higher elevations and V-shaped in the lower canyon. The path of Johnston Creek has changed since the last glacial advance.

(a) Utilizing your knowledge of the erosive power of running water, explain why the lower canyon is V-shaped. Suggest when the lower canyon may have been formed.

(b) Scientists regard the presence of a terminal moraine in Johnston Creek as evidence that a glacier once flowed down the valley. Suggest the basis for this belief.

(c) Considering the above data, formulate a theory to explain the U-shape of the upper valley.

(d) Build a laboratory model to illustrate the erosive power of running water. Dribble water down a slope of loose sand and gravel. Observe how the water collects and flows down the path of least resistance. Note carefully the order in which material is picked up and deposited.

3 **Background information**
A terminal moraine lies at the end of the U-shaped upper valley. It is a pile or ridge of rock pushed ahead of a glacier and deposited upon its retreat. A massive slump of rock covering an area of ten square kilometres appears to have slid away from the shoulder of Mount Ishbel. Johnston Creek once emptied into the Bow River four kilometres east of its present course.

(a) Suggest a theory to explain what effect the last Ice Age may have had on the course of Johnston Creek.

(b) Formulate another theory explaining how the stream course may have been affected by the rock slump from the shoulder of Mount Ishbel.

(c) Scientists have observed that water follows the path of least resistance. Explain how this observation is relevant to your answers to questions (a) and (b) above.

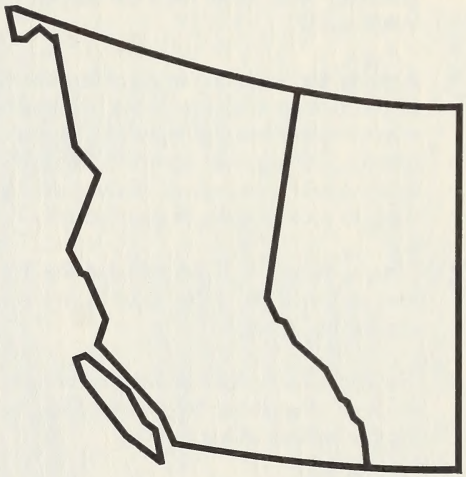
(d) Utilizing the model previously designed by students (science-process question 2d), divert the "stream's" course. Drop a clump of sand and gravel on the "creek" and observe how the water finds an alternate route. Block the stream, simulating the effect of the terminal moraine, and observe the route of the "creek" once again. Utilizing your observations, speculate upon the most probable reason for Johnston Creek's change in direction.

N.B. For approach of questions incorporating science-process skills, see page 4.

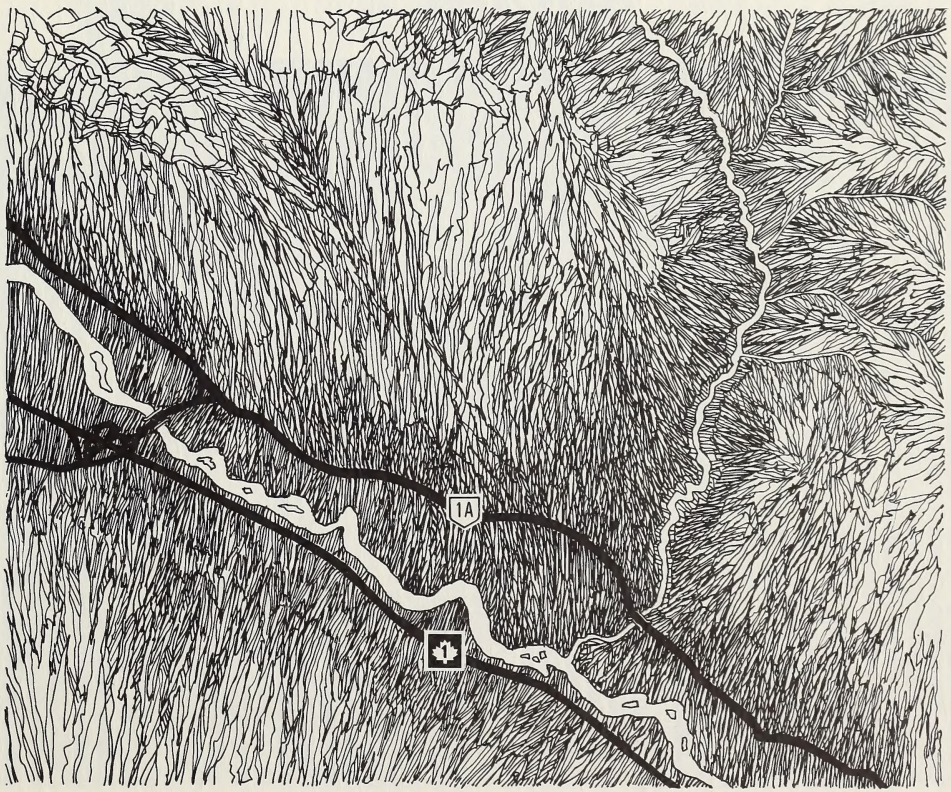
Activity questions

1 Label the following places on the maps provided:

Map 1
(a) Alberta
(b) British Columbia
(c) Banff National Park
(d) Town of Banff.



Map 2
(e) Johnston Canyon
(f) Johnston Creek
(g) Bow River.



Activity questions

2 One of me – or a hundred of me – have no effect on rock that the eye can see. But given time, I can gradually wear away even the hardest rock. What am I?

3 Arrange the following in an order that tells the story of the formation of the Rocky Mountains: glacial erosion; compression; deposition of sediments; folding, faulting, and upthrust. Research approximate time periods of these events and relate them to rock samples in your school.

4 Draw a picture to illustrate what the Johnston Creek area and the Bow Valley may have looked like during the Ice Age.

5 The rocks I am made of were carried and pushed by the nose of a glacier. When the glacier retreated, it left me behind. What am I?

6 Match up the following:

marine organisms	shale
sand	limestone
silt	sandstone

7 Arrange the following in an order that tells the story of the formation of Johnston Canyon: terminal moraine; glacial advance; water erodes the rock into a steep V-shaped valley; slump of rock from the shoulder of Mount Ishbel; Johnston Creek changes its path.

8 See how good a detective you are. Underline the six lies told by this witness, Sedimentary Rock.

My name is Sedimentary Rock. I was formed millions of years ago, at the bottom of a great sea. This sea once covered most of Canada. Deposits of sand and shale were compressed, forming my layers. Then, powerful forces bent and broke me and threw me high up into the air over the Pacific Ocean. Water from glacial runoff streamed down my sides, cutting a steep, V-shaped valley. The Ice Age brought glaciers, which gouged out my canyon, making it steeper than ever. Water still erodes me, forming a creek that flows into the Elbow River.

Activity questions

9 Locate the following landmarks on the map and then paint it:

- **(a)** Mount Ishbel
- **(b)** Castle Mountain
- **(c)** rain and snow melting and flowing
- **(d)** into various smaller streams
- **(e)** which in turn feed Johnston Creek
- **(f)** U-shaped upper valley
- **(g)** terminal moraine
- **(h)** Johnston Creek winding down towards the Bow River
- **(i)** Pulsatilla Pass
- **(j)** V-shaped lower valley
- **(k)** Shale Canyon
- **(l)** Upper Falls
- **(m)** Lower Falls
- **(n)** alluvial fan.

Answers to subject questions

1 The power of water to erode rock, and how water has created the landscape features evident in the Johnston Creek area.

2 Twenty-five kilometres west of Banff in Banff National Park. Entrance to the lower canyon (Johnston Canyon) is made where the Bow Valley Parkway crosses Johnston Creek near its junction with the Bow River.

3 Pulsatilla Pass, where runoff from rain, melting ice and snow accumulates and begins to wander down a line of weakness between the Front and Main ranges of the Rocky Mountains.

4 Sedimentary rock.

5 Sand, silt, and the remains of marine organisms were deposited on the bottom of ancient seas, which once covered most of western Canada. These bottom layers were then compressed into (sedimentary) rock by the enormous weight of the layers deposited above them.

6 (a) Sandstone, (b) shale or siltstone, and (c) limestone.

7 Approximately 100-140 million years ago, powerful forces within the earth began to squeeze the ancient seabed, bending and breaking it into great slabs, which were then thrust up and over each other. Continuous pressure forced these gigantic rock masses eastward over the Canadian plains.

8 The rock layers differ in their resistance to erosion. Therefore, the same amount of water will erode different rocks at different rates.

9 V-shaped. The ancestral Johnston Creek wandered down a line of weakness, sawing through the various layers of rock and creating a V-shaped valley.

10 There is a terminal moraine at the end of the upper valley. The glaciers ground against the sides and floor of the valley, broadening it into the U-shape present today.

11 A massive slump of rock from the shoulder of Mount Ishbel, or the terminal moraine deposited by the last glacial advance. In either situation, the debris blocked the original course of Johnston Creek, forcing it to carve a new path.

12 Another channel, and new canyons and waterfalls.

13 In the course of the last 7 - 10 000 years.

Answers to science-process questions

Numbers following the answers refer to process skills listed in the inventory on Page 4.

1 (a) The sediments were deposited layer after layer, like a huge layer cake. (Skills: 7, 2, 14)

(b) The sediments were deposited at the bottom of an ancient sea, which once covered most of what is now western Canada. (Skills: 4, 8, 11)

(c) Approximately 100-140 million years ago, powerful forces within the earth began to squeeze the ancient seabed, bending and breaking it into giant slabs of rock. These rocks were then thrust up and over each other. (Skills: 4, 8)

(d) Different colors of plasticene could simulate the different strata or layers of sediments. By manoeuvering the wax paper, the "sediments" could illustrate the arching, folding, and thrusting caused by the earth's internal forces. (Skills: 5, 11, 17)

2 (a) When Johnston Creek changed direction following the last glacial advance, it eroded a canyon with steep, V-shaped sides. (Skills: 4, 11)

(b) A "terminal moraine" is a ridge or pile of rock and debris pushed ahead of a glacier and deposited upon its retreat. A terminal moraine can mark the farthest point of a glacial advance. (Skills: 4, 11, 14)

Answers to science-process questions

(c) Johnston Creek eroded a steep, V-shaped valley en route to the Bow River. During the last glacial advance, glaciers ground rock and debris from the sides of the upper valley, broadening it into a wide, "U" shape. (Skills: 5, 12, 7)

(d) Depending on the scale of the model, and therefore the erosive power of the water, students could observe either, or both, of the following:

(1) smaller, looser material is carried away more easily by the water, while heavier material remains. (Skills: 6, 7)

(2) larger, heavier material settles out at the base of the slope earlier than the more soluble smaller particles, which are carried farther. (Skills: 6, 7)

3 (a) The terminal moraine may have blocked the path of Johnston Creek, forcing it to find a new route. (Skills: 4, 11)

(b) The tonnes of material from the massive rock slump may have diverted the creek. (Skills: 4, 11)

(c) Johnston Creek changed its course because less resistance was met in carving a new route than in flowing through either the terminal moraine, the rock slide, or both. (Skills: 4, 11)

(d) Johnston Creek may have been diverted by the terminal moraine, the rock slide from the shoulder of Mount Ishbel, or both. Since the actual cause cannot be proven, students may take any of the three points of view, as long as their opinions are well-supported. (Skills: 4, 11)

Answers to activity questions

1 (Map with answers) see page 12

2 A drop of water.

3 Deposition of sediments;
compression;
folding, faulting, and upthrust;
glacial erosion.

5 A terminal moraine.

6

Marine organisms	. . .limestone
Sand	. . .sandstone
Silt	. . .shale

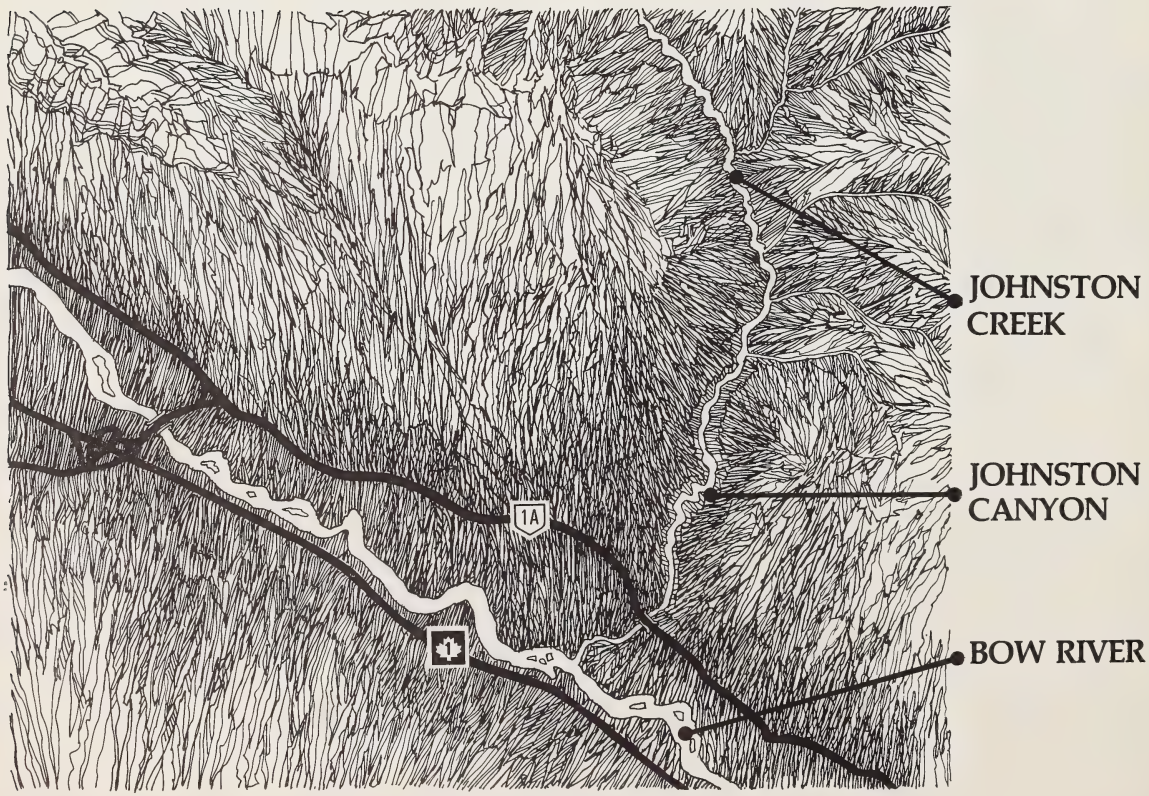
7 Glacial advance;
terminal moraine;
slump of rock from the shoulder of Mount Ishbel;
Johnston Creek changes its path;
water erodes the rock into a steep, V-shaped valley.

8 My name is Sedimentary Rock. I was formed millions of years ago, at the bottom of a great sea. This sea covered **most of Canada.** Deposits of sand and **shale** were compressed, forming my layers. Then, powerful forces bent and broke me and threw me high up into the air over the **Pacific Ocean.** Water from **glacial runoff** streamed down my sides, cutting a steep, V-shaped valley. The Ice Age brought glaciers, which gouged out my canyon, **making it steeper than ever.** Water still erodes me, forming a creek that flows into the **Elbow River.**

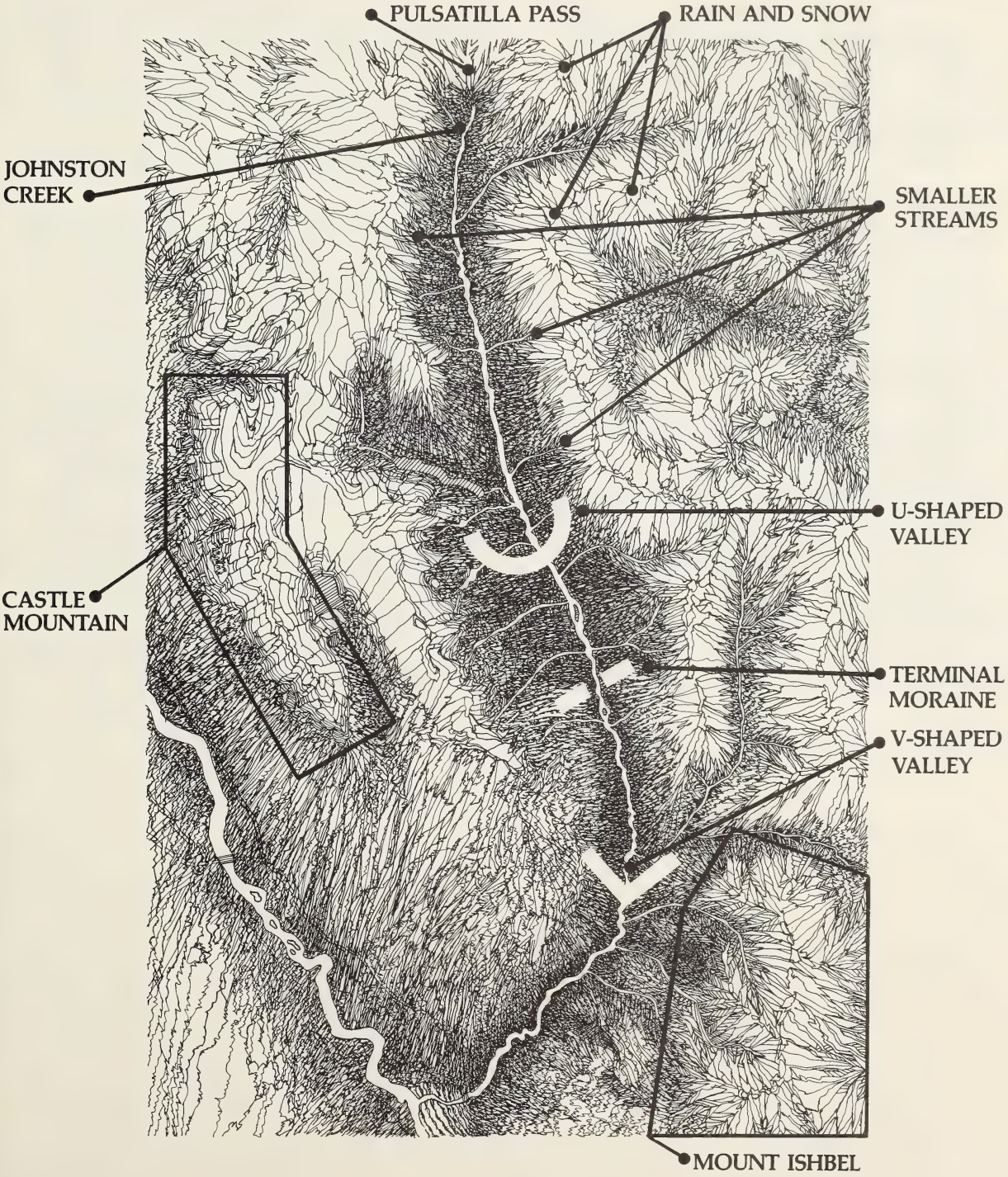
9 (Map with answers) see page 13

Answers to activity questions

1



9


PULSATILLA PASS
RAIN AND SNOW
JOHNSTON CREEK
SMALLER STREAMS
U-SHAPED VALLEY
CASTLE MOUNTAIN
TERMINAL MORAINE
V-SHAPED VALLEY
MOUNT ISHBEL

Subject questions

1 Approximately when did the last glacier retreat from the Johnston Creek area?

2 What is glacial till?

3 What was the impact on the glacial till of the meltwater from the retreating glacier?

4 Where is Shale Canyon located in relation to Johnston Canyon? Was it formed by the glacial meltwater? What type of deposits did Johnston Creek erode to create Shale Canyon?

5 Describe how shale is formed.

6 What happens to shale under the force of rushing water?

7 What is the name given to describe this type of erosion? What is meant by this term?

8 How does the appearance of Johnston Canyon differ from that of Shale Canyon?

9 Why do Johnston Canyon and Shale Canyon contrast so sharply?

10 What is the rock structure of Johnston Canyon?

11 What type of erosion predominates in Johnston Canyon?

12 Briefly describe how this process of erosion occurs.

13 To what group of rocks do limestone and dolomite belong?

14 What chemical components make up this rock group?

15 How do geologists differentiate between limestone and dolomite?

16 Although Johnston Canyon is sculptured primarily by chemical erosion, it is also subject to one form of mechanical erosion: abrasion. What occurs when a canyon floor is eroded by abrasion?

17 During the formation of Shale and Johnston Canyons, enormous amounts of rocky material were moved and transported down Johnston Creek toward the Bow River. What happened to the rocky material where the creek met the Bow Valley?

18 What causes the formation of an alluvial fan at this point?

19 In what "order" is rocky debris – silt, boulders, sand, and gravel – dropped? Does the alluvial fan contain all of the material that was washed out of the canyon?

20 Why is the Johnston Creek/Bow Valley alluvial fan presently overgrown by vegetation?

Science – process questions

1 **Background information**
The rock of Shale Canyon consists of shale and glacial debris. The shale was formed when innumerable thin layers of fine silt were deposited at the bottom of an ancient sea and slowly transformed into a soft, brownish rock.

(a) Utilizing the above data on the formation of shale, explain why this rock is so fragile.

(b) Utilizing the above data, predict what type of erosion shale is susceptible to and explain your reasoning.

(c) Obtain a small sample of shale. Observe its layered appearance. Break off a piece. Describe how it broke. Relate your description to the formation of shale.

2 **Background information**
The bedrock of Johnston Canyon is comprised of limestone and dolomite. These (carbonate) rocks are susceptible to a slow process of erosion that occurs when a reaction takes place with slightly acidic water. Limestone dissolves much more readily than dolomite.

(a) Utilizing the background information, suggest a suitable name for the erosion process described above and explain your reasoning.

(b) By comparing the processes of erosion described in questions 1, page ____, and 2, page ____, illustrate how they have created the difference in appearance between Johnston Canyon and Shale Canyon.

3 **Background information**
To differentiate between limestone and dolomite, scientists conduct a simple test in which a few drops of hydrochloric acid are placed on samples of these rocks. Conduct this experiment in your classroom. You will require the following materials: samples of limestone and dolomite, a glass eye-dropper, HCL.

(a) Using the eye-dropper, place a few drops of HCL on each sample. Observe the reaction. Which sample is dolomite? Which sample is limestone? Explain your reasoning.

4 **Background information**
During the formation of the two canyons, enormous amounts of rock debris were carried down Johnston Creek toward the Bow River. At the point of intersection, the material was deposited in the form of an alluvial fan. Johnston Canyon is narrow and has steep walls. Where Johnston Creek enters the Bow Valley, the stream bed widens.

(a) Utilizing the above information, formulate a theory to explain why the creek deposited its load of debris where it enters the Bow Valley.

N.B. For approach of questions incorporating science-process skills, see page 4.

Activity questions

1 Locate the following on the map: Shale Canyon, Upper Falls, Lower Falls, alluvial fan, Bow River.

Activity questions

2 I am the tonnes of material that was picked up and carried by a glacier and then dumped on the valley floor upon its retreat. What am I?

3 When you look at me, you can still see my original layers. I look like a stack of wafers. What am I?

4 Draw a cross section of a piece of shale.

5 I scratch and scrape the floors and walls of Johnston Canyon, chipping off bits of rock. What am I?

6 Place the following under one or other of the headings provided below:

(a) calcium carbonate
(b) calcium magnesium carbonate
(c) resistant to water erosion
(d) soluble in acidic water
(e) will foam abundantly when in contact with hydrochloric acid (HCL).

Limestone	Dolomite

7 I am the name given to the group of rocks to which limestone and dolomite belong. They are composed of carbon and oxygen joined to other elements. What am I?

8 Choose sides to play charades. Decide what your ground-rules are. Act out concepts from Program 2. Don't try to guess the exact words of the charade, just identify the idea. Concepts might come from the following:

(a) Upon their retreat, glaciers dumped tonnes of rock and debris on the valley floor.
(b) Water eroded through thick deposits of rock debris and shale to form Shale Canyon.
(c) Johnston Canyon is steep and narrow, and the creek descends in waterfalls.
(d) Shale is made up of many layers, which are easily chipped.
(e) Pieces of rock carried by rushing water bounce around, scratching and scraping the canyon walls.
(f) The heaviest pieces of rock are the first to be dropped when the creek slows down.

9 Paint or sketch your own picture of Johnston and Shale canyons.

10 See how good a judge you are. Underline the six lies in the testimony of this witness, Johnston Canyon.

I am Johnston Canyon. Carved by Johnston Creek, I am upstream from Shale Canyon. My bedrock is made up of limestone and dolomite. Known as carbonates, these rocks are made up of carbon dioxide. My rock is formed in layers and is easily eroded. When the alkaline water of Johnston Creek tumbles over my dolomite, it becomes soluble calcium bicarbonate. This process is known as mechanical erosion.

11 Write your own legend telling the story of the formation of Johnston Canyon and Shale Canyon.

Answers to science-process questions

Numbers following the answers refer to process skills listed in the inventory on Page 4.

1 (a) The original layered structure of the ancient silts can still be observed in shale. It resembles a stack of wafers. (Skills: 1, 8)

(b) Mechanical erosion. Because shale still retains its original layered structure, it can be split into flat pieces and easily dislodged. Under the force of rushing water, shale is carried away piece by piece. (Skill : 3)

(c) Shale is easily broken. As it still retains its layered structure, shale can be broken off in layers. (Skill : 4)

2 (a) Chemical erosion. It occurs through a chemical reaction between water and rock. (Skill: 11)

(b) (1) When rock is fragmented and carried away by the force of running water, the process is called mechanical erosion. The result is jagged rock – the kind of rock face found in Shale Canyon. (Skills: 11, 12)

(2) In the process of chemical erosion, the chemical components are washed away and the rock is slowly broken down. The result of this "micro" erosion is smooth, highly-polished stone – the kind of stone facing and features found in Johnston Canyon. (Skills: 11, 12)

3 A few drops of hydrochloric acid placed on limestone will cause abundant foaming, whereas acid on dolomite causes little bubbling. (Skill: 5)

Note: There is a natural gradient between limestone and dolomite, its extent depending upon the chemical make-up of the rock in question. Results will depend upon the particular rock samples used.

4 Where the canyon is steep and narrow, Johnston Creek flows at high speeds and is able to carry large amounts of rock. At its point of intersection with the Bow Valley, the stream bed widens, the slope decreases, and the water slows down. Johnston Creek loses its ability to carry heavy debris and drops it. (Skills: 2, 4, 11)

Answers to subject questions

1 About 7 - 10 000 years ago.

2 Upon the retreat of a glacier, all the rock and debris that had been picked up and carried along is dumped. This debris is called glacial till.

3 The meltwater swept most of the glacial till out of the upper valley.

4 Upstream from Johnston Canyon. Yes. Thick deposits of shale and glacial debris.

5 Innumerable layers of fine silt were deposited on the bottom of warm ancient seas. Subjected to the enormous weight of subsequent sedimentation, they were slowly transformed into shale – a soft, brownish rock.

6 It separates into flat pieces, which are easily dislodged.

7 Mechanical erosion, meaning destruction by a physical force such as running water.

8 Johnston Canyon is deep and narrow with steep, smooth walls. Shale Canyon is wider with ragged walls.

9 The two canyons were formed from different kinds of rock. These rocks are susceptible to water erosion in different ways.

10 Limestone and dolomite.

11 Chemical erosion.

12 It occurs through a chemical reaction between water that is slightly acidic, and rock.

13 Carbonates.

14 Carbon and oxygen, joined with other chemical elements.

15 A few drops of hydrochloric acid (HCL) placed on limestone cause abundant foaming. Drops of HCL on dolomite cause little bubbling.

Answers to subject questions

16 Abrasion occurs when pieces of rock carried by turbulent water bounce around, scratching and scraping canyon floor, and chipping off bits of rock.

17 The rocky material – boulders, pebbles, gravels, and sands – was dropped in the form of an alluvial fan.

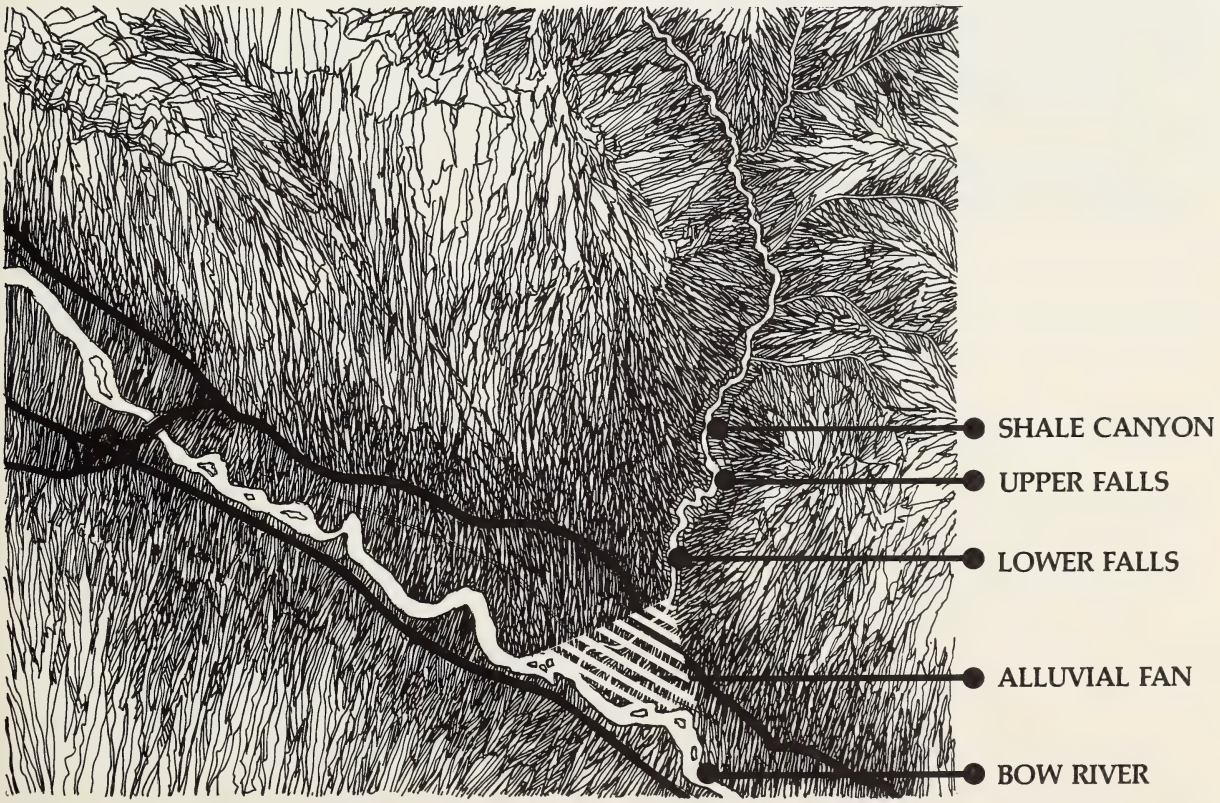
18 When Johnston Creek enters the Bow Valley, the stream bed widens, the slope decreases, and the water slows down. The creek loses its ability to carry the debris and drops it.

19 The heaviest boulders are dropped first, then the coarse gravels, and eventually silt. No. Some of the lightest material is carried into the Bow River and may even reach Hudson Bay eventually.

20 The present rate of erosion and deposition is slower than that of a few thousand years ago, and plant species have colonized the stable areas of the fan.

Answers to activity questions

1

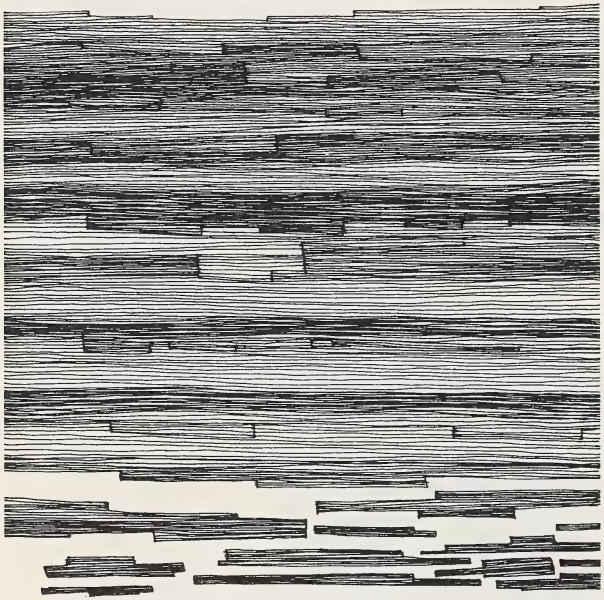


Answers to activity questions

2 Glacial till

3 Shale

4 Cross-section of shale



5 Abrasion

6

Limestone	Dolomite
– calcium carbonate – soluble in acidic water – will foam abundantly when in contact with hydrochloric acid (HCL).	– calcium magnesium carbonate – resistant to water erosion

7 Carbonates

10 I am Johnston Canyon. Carved by Johnston Creek, I am **upstream** from Shale Canyon. My bedrock is made up of limestone and dolomite. Known as carbonates, these rocks are made up of **carbon dioxide.** My rock is formed in layers **and is easily eroded.** When the **alkaline water** of Johnston Creek tumbles over my dolomite, it becomes **soluble calcium bicarbonate.** This process is known as **mechanical erosion.**

Subject questions

1 How many waterfalls are there in Johnston Canyon?

2 Like a hard crust on snow, dolomite forms a cap on top of softer layers of limestone. How does the dolomite cap protect the underlying layers of limestone from immediate erosion?

3 Why is the dolomite also referred to as the lip? When the dolomite lip eventually breaks off, what is created in time?

4 What is the depression at the base of a falls called? How is it created?

5 What does a chain of old, overlapping plunge pools create?

6 A dry falls stands about one hundred metres to the west of the Upper Falls. What does this imply with regard to the course of Johnston Creek?

7 Travertine is formed by certain plants in areas that are rich in limestone and moistened by flowing water. What are these plants called?

8 What chemical or rock enfolds these tiny plants?

9 How is travertine formed?

10 How can depressions caused by undercut meanders be located high on the canyon walls?

11 Smoothly polished oval depressions can sometimes be seen in an exposed piece of limestone on the floor of Johnston Canyon. What are these depressions called?

12 Describe the effect of spring meltwater on the process of erosion.

13 Water, caught in a crack, expands as it freezes. Acting as a small but powerful wedge, it can pluck flakes of material from the surface of rock or split rock. What is this process called? When is it most active?

14 How old is Johnston Canyon?

Science – process questions

1 **Background information**
In Johnston Canyon, there are seven waterfalls that look like steps in a gigantic staircase. These steps occur where a dolomite "cap" protects the underlying, softer layers of limestone. At the base of each waterfall, the churning water gradually scoops out a depression known as a plunge pool.

(a) Utilizing the background information, describe the effect that the continuous pounding of Johnston Creek has on the underlying limestone layers.

(b) Speculate as to what effect the eroding limestone has on the distance the water drops.

(c) As further erosion of the limestone occurs, predict the outcome for the dolomite cap.

(d) As each waterfall is born in Johnston Canyon, so is its plunge pool, the water-filled depression in the limestone at its base. Scientists have observed that the plunge pools of high waterfalls are deeper than those of low ones. Utilizing the information given, and specifically your answer to question (b) above, suggest a reason for this observation.

(e) Organize the data to formulate a theory describing the formation of a plunge pool.

2 **Background information**
Travertine drapes are formed, in part, by various species of algae. Travertine can be found along the canyon walls to the south and west toward the Upper Falls.

(a) Recall the environment of Johnston Canyon. What elements - for example, the type of light – are necessary for travertine to grow?

(b) Comparing the growth of the travertine drapes with the formation of coral reefs, formulate a theory explaining how the algae continually create travertine. You may wish to include a diagram in your answer.

Science – process questions

3 **Background information**
Johnston Creek carves a path down to the Bow River. From the suspended pathway in Johnston Canyon, the stream is not always visible. In some places, it disappears into the base of the cliff. Where the force of the creek is directed at the softer limestone, the wall is eroded away. This is an "undercut meander."

(a) Analyze the above data to formulate a theory explaining why depressions are located high on the walls of the canyon.

4 **Background information**
During the formation of Johnston Canyon, enormous amounts of rocky material were removed and transported down Johnston Creek. At the base of each waterfall, a plunge pool was formed. Smoothly polished depressions called "scallops" can sometimes be seen in the exposed limestone floor of the canyon. Scientists are not sure how they were formed.

(a) Utilizing the background information, describe how the circular action of water and rock debris creates plunge pools.

(b) Utilizing the above information, describe the similarity in process that may have created both plunge pools and scallops.

5 **Background information**
Water, caught in a crack, expands as it freezes. Acting as a small but powerful wedge, it can pluck flakes of material from the surface of rock or split rock.

(a) When would the freeze/thaw process be most active?

(b) Using the background information, explain how this process could split an entire rock.

(c) Organize the data to formulate a theory suggesting how the freeze/thaw cycle affects the process of erosion.

6 **Background information**
In the spring, snow melts in the Johnston Creek area, greatly increasing the volume of Johnston Creek.

(a) Utilizing the background information, speculate about the amount of rock debris transported by Johnston Creek in the spring.

(b) Utilizing the above information, formulate a theory explaining how spring affects the erosion of Johnston Canyon. Specify the role of rock debris in the process.

N.B. For approach of questions incorporating science-process skills, see page 4.

Activity questions

1 Arrange the following in an order that describes the creation of a waterfall: a waterfall is created in time; limestone underneath cap is dissolved and abraded; undercut dolomite eventually breaks off; dolomite cap protects underlying layers of softer limestone; water falls great distance over cap.

2 I am the depression at the base of a waterfall. Spinning water flowing over the falls gradually scoops out my bowl. The higher the falls, the deeper my basin. What am I?

3 About 100 metres west of the Upper Falls stands a dry falls. Sketch a drawing depicting Johnston Creek's old course. Be sure to include the stream's present course as well.

4 You are a science-fiction painter. Make a colorful picture of the travertine drapes located near the Upper Falls.

Activity questions

5 Choose sides to play charades. (See Program 2 – Activity Questions #8.) Don't try to guess the exact words of the charade, just the concept. Ideas might come from waterfall formation, plunge pool formation, travertine drapes, undercut meanders, the freeze/thaw cycle of water caught in a rock, and from the increased erosion of Johnston Canyon in spring.

6 Arrange the following in an order that explains the freeze/thaw cycle: water freezes and expands; small rock particles; water in crack; crack; rock; ice splitting the rock apart.

7 Experiment:

(a) Pour some water into an open jar and mark the water level.
Freeze.
How much did the volume change?
Calculate a formula to measure this expansion.

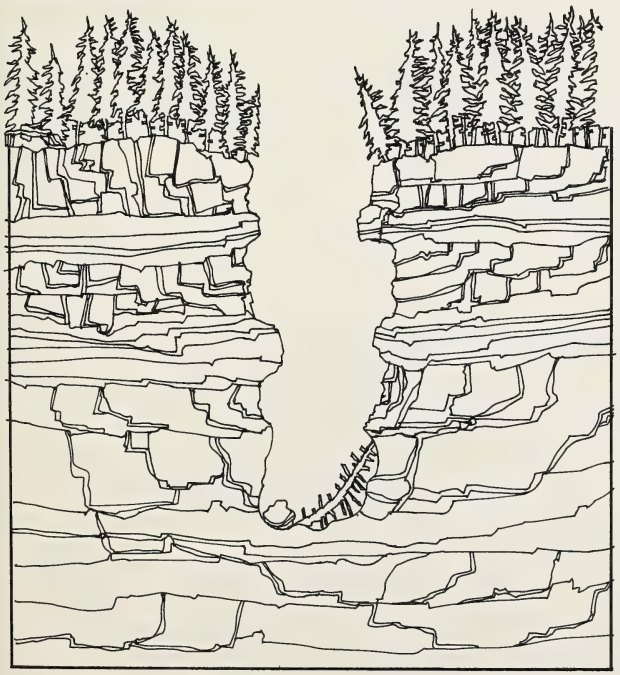
(b) Completely fill a jar with water.
Seal tightly.
Freeze.
What happened to the jar when the water froze?
Explain how this experiment relates to the effects of water and ice on rock.

8 In a series of sketches, show how depressions formed by an undercut meander were left high on the walls of Johnston Canyon.

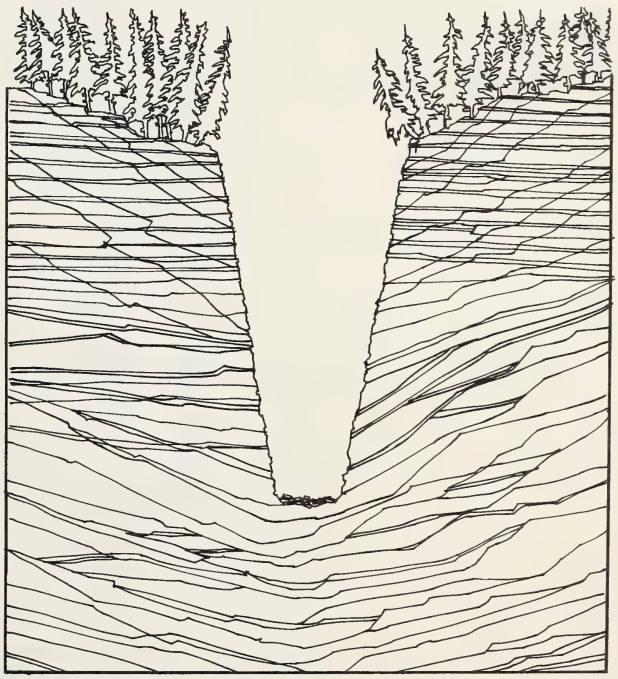
9 Write a poem telling how spring meltwater changes Johnston Creek into a raging torrent, which picks up and carries debris along to gouge further the canyon walls.

10 Illustrate what these rock profiles might look like ten thousand years from now, if they were to be eroded by water.

Limestone and Dolomite



Shale



Answers to subject questions

1 Seven.

2 Since dolomite is more resistant, the dolomite cap remains while the soft limestone underneath is dissolved and abraded.

3 The falling water slowly undercuts the dolomite by dissolving the limestone underneath, and a dolomite lip is formed.

4 A plunge pool. The spinning water gradually scoops a bowl at the base of the falls.

5 A canyon.

6 Johnston Creek once had a different course and flowed over the Dry Falls.

7 Algae.

8 Limestone or calcium carbonate.

9 By the process of the algae repeatedly becoming encrusted and growing outward to form travertine.

10 In time, water erodes the canyon floor downward, leaving the depressions "suspended" on the canyon walls.

11 Scallops.

12 The volume of meltwater and its abrasive load speeds the process of erosion.

13 The freeze/thaw process. It occurs in both spring and fall, when temperatures hover around the freezing point but is most active in the spring, because there is more meltwater.

14 Eight to ten thousand years old.

Answers to science-process questions

Numbers following the answers refer to process skills listed in the inventory on Page 4.

1 (a) Since the dolomite cap is more resistant to water erosion, it remains while the softer limestone underneath is dissolved. (Skills: 2, 11)

(b) As the limestone erodes, the water flowing over the dolomite cap falls a greater distance. (Skills: 3, 11)

(c) As the falling water slowly undercuts the limestone, the dolomite cap becomes a "lip". As the lip is extended farther and farther, it eventually breaks off. (Skill: 3)

(d) The higher the falls, the greater the force of falling water. (Skills: 2, 8, 11)

(e) Water tumbling over the dolomite ledge hits the base of the falls with an explosive force. The spinning water gradually scoops out a depression at the base of the falls. (Skill: 14)

2 (a) Travertine forms in areas where there is low light, high moisture, and cool temperatures. It is formed in areas that are rich in limestone and moistened by flowing water. (Skills: 5, 3)

(b) The algae grow out, become encrusted, and grow out once again. This process continues, layer upon layer, to weave the delicate texture of travertine. (Skills: 4, 8, 17)

3 (a) As time passes, and the canyon floor is eroded away, huge depressions formed by undercut meanders are left high on the canyon walls. (Skills: 1, 12)

4 (a) Plunge pools are formed when water, and the rock debris it carries, hit the base of the falls, churning and swirling around, dissolving and abrading the limestone. (Skill: 7)

(b) Rock debris, whirled around by eddies, could carve this feature in less resistant limestone. (Skills: 11, 12)

5 (a) The freeze/thaw process is active in both spring and fall, when temperatures hover around the freezing point. However, this process is most active in spring because of the abundance of meltwater. (Skill: 3)

Answers to science-process questions

(b) A drop of water caught in a small crack of a rock expands when it freezes. This enlarges the crack. When the ice thaws, more water is trapped. When the water freezes, the crack is split open even more. This process continues until the rock itself eventually splits. (Skills: 2, 4)

(c) Since the freeze/thaw process can break down rocks into smaller particles, it hastens erosion. (Skills: 11, 12)

6 (a) The amount of rock debris transported by Johnston Creek increases in the spring because the volume of water is greater. (Skill: 4)

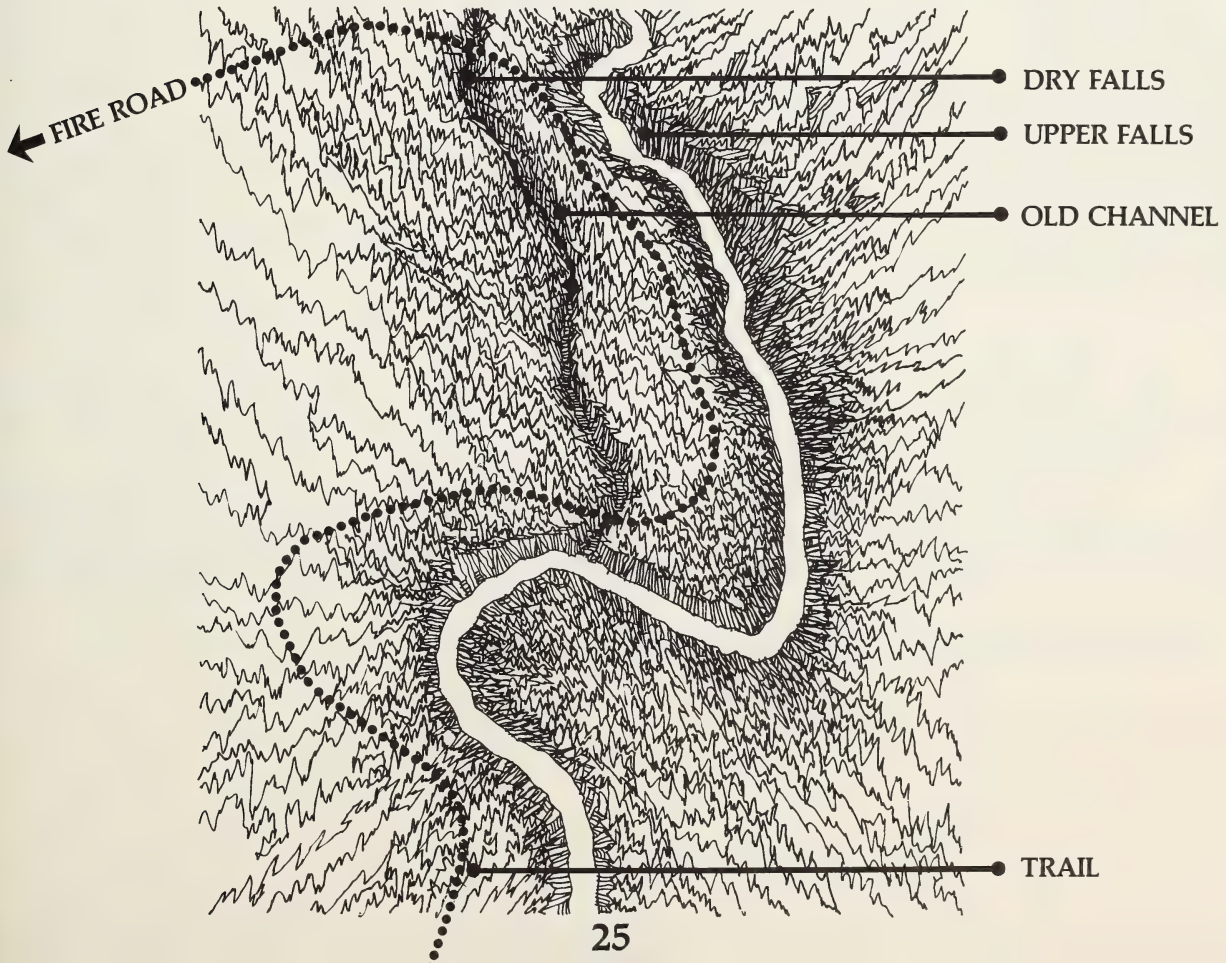
(b) The increased meltwater and the amount of abrading rock debris it carries, speeds the process of erosion during spring. (Skill: 12)

Answers to activity questions

1 Dolomite cap protects underlying layers of softer limestone;
limestone underneath cap is dissolved and abraded;
water falls distance over cap;
undercut dolomite eventually breaks off;
in time, a waterfall is created

2 A plunge pool.

3 (Map with answers)



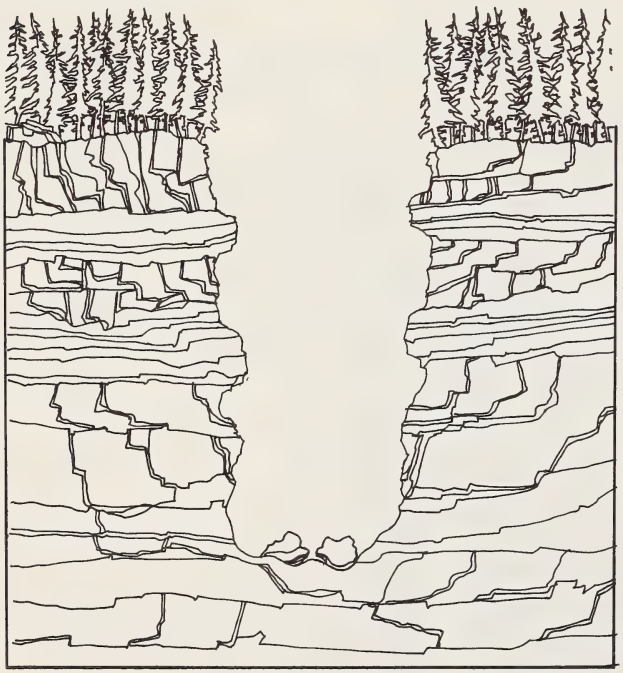
Answers to activity questions

6 Rock;
crack;
water in crack;
water freezes and expands;
ice splitting the rock apart;
small rock particles.

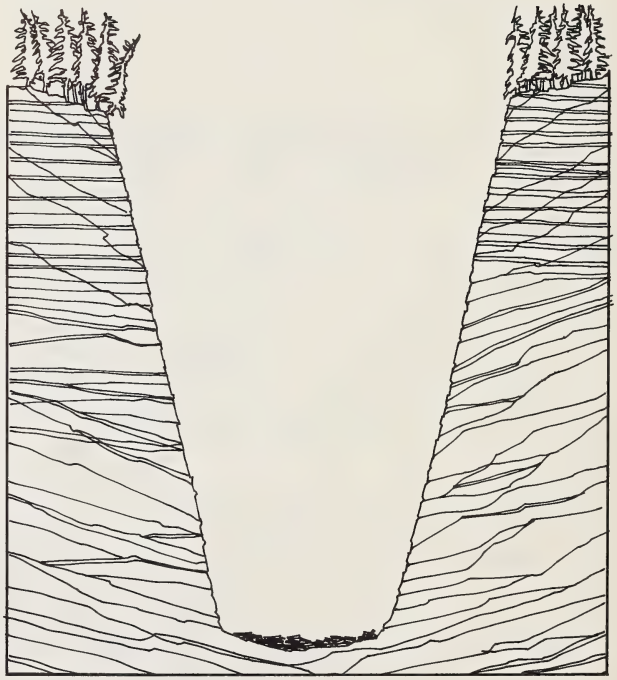
7 (b) Either the jar broke or the cap (being flexible) bulged. When water freezes, it expands. In expanding, it breaks down the substance that contains it.

10

Limestone and Dolomite



Shale



Subject questions

1 Where is Johnston Canyon located?

2 What are the Ink Pots?

3 Why do the pools have a turquoise/blue color?

4 How was the alluvial fan formed?

5 Describe the present appearance of the fan.

6 What process of erosion carved Shale Canyon?

7 Briefly describe the process that sculptured Johnston Canyon.

8 Briefly explain the formation of a waterfall.

9 What lies at the bottom of a waterfall?

10 Name a species of bird that has made the canyon its home.

11 At least four kinds of small mammals can be found in the Johnston Canyon area. Name two.

12 At least four kinds of large mammals pass through the Johnston Canyon area. Name two.

13 At least four different types of trees grow along the Canyon edge. Name two.

14 Johnston and Shale canyons are only two areas in the Rocky Mountains where water-sculptured landscapes can be found. Name one other area.

15 Where is the Columbia Icefield? What is its significance to Johnston Creek?

16 Suggest one reason why Canada has national parks.

Science – process questions

1 **Background information**
The Ink Pots are seven, cold-water pools tinged in colors of blue and turquoise. They contain a large amount of rock flour in suspension. This fine silt absorbs most of the sunlight that penetrates the water, reflecting only colors of the blue-green spectrum.

(a) Using the information provided, formulate a theory explaining the different colors of the pools.

(b) The presence of rock flour in the Ink Pots provides a clue to the story of the sculpturing of the Johnston Creek area. Briefly, explain this connection.

2 **Background information**
Canada's national parks are among the finest in the world. Within them, natural landscapes are preserved and protected as part of the fabric that has woven our history.

(a) Explain why the Johnston Creek area deserves Parks Canada's efforts to preserve and protect it.

(b) To what extent has Parks Canada attempted to make the area as accessible and attractive to the public as possible?

(c) Who is responsible for the preservation and protection of these special areas?

3 **Background information**
The official policy of Parks Canada states:

"The parks are hereby dedicated to the people of Canada for their benefit, education, and enjoyment . . . and such parks shall be maintained and made use of so as to leave them unimpaired for the enjoyment of future generations."

(a) Utilizing this information, consider the reasons for this policy. Do you agree with this policy? Substantiate your answer.

N.B. For approach of questions incorporating science-process skills, see page 4.

Activity questions

1 Label the following places on the map:

(a) Alberta
(b) British Columbia
(c) Banff National Park
(d) Jasper National Park
(e) Yoho National Park
(f) Columbia Icefield
(g) Lake Louise
(h) Banff
(i) Johnston Canyon
(j) Bow River.

Activity questions

2 I am a turquoise blue color. There are six others like me. My flour is kept in constant turmoil by water percolating up from below. What am I?

3 Arrange the following in an order that tells the story of the formation of Johnston Canyon:
water erodes the rock into a steep, V-shaped valley;
glacial meltwaters sweep the canyons clean of till;
deposition of debris forms an alluvial fan;
great slabs of stone are pushed into the sky;
glaciers grind the upper valley into a wide "U" shape;
water erodes the rock into a steep, V-shaped valley;
water erodes a wide trough.

4 Place the following under the appropriate headings of mechanical or chemical erosion:
- smooth, polished features
- pieces are dislodged by the force of rushing water
- Shale Canyon
- water dissolves chemical elements in rock
- rough, ragged appearance
- Johnston Canyon

5 How good is your memory? Sketch the self-guiding trail beside Johnston Creek, identifying the points of special interest.

6 Draw some cross section diagrams that illustrate how travertine is formed. Remember that limestone, water, and algae are some of the essential elements.

7 I am the depression at the base of a waterfall. Spinning water flowing over the falls gradually scoops out my bowl. The higher the falls, the deeper my basin. What am I?

8 I am on the border between Banff and Jasper National Parks. I still contain glaciers. My ice and meltwater are shaping the land just as the Johnston Creek area was sculptured by ice thousands of years ago. What am I?

9 Sketch a picture of the Johnston Canyon landscape. Include some of the wildlife that inhabit the area. The drawings could show: dipper, golden-mantled squirrel, chipmunk, black bear or grizzly, lynx or coyote.

10 I am a preserved and protected area of Canada's natural landscape. I am considered one of the finest in the world. The responsibility for my maintenance rests with the public. What am I?

11 You are a naturalist. Your employer, Parks Canada, has just asked you to write a brochure describing the Ink Pots to visitors. Write the description and provide suggestions for colorful illustrations.

12 Identify two trees found in the Johnston Canyon area.

13 List as many national parks as you can. Circle all the parks you've visited.

14 Draw or paint a picture illustrating how you think Johnston Canyon or Shale Canyon may look a million years from now. You might include waterfalls, plunge pools, travertine drapes, depressions made by undercut meanders. Recall how each of these features changes with time. Add your own personal touch to let the viewer know that it is a picture of the distant future.

Answers to subject questions

1 In Banff National Park, twenty-five kilometres west of the town of Banff along the Bow Valley Parkway.

2 Seven pools tinged in colors of blue and turquoise.

3 Fine silt or rock flour is suspended in the water. Sunlight penetrating the cold water is mostly absorbed by these particles. Only the colors of the blue-green spectrum are reflected to our eyes. The particles are kept in constant turmoil by water percolating up from below. Varying amounts of silt give each pool a different hue.

4 Tonnes of glacial till were swept down the course of Johnston Canyon by meltwater. When the water spilled into the much broader Bow Valley, it dropped its rocky load in the shape of a huge fan.

5 Overgrown by trees, the site of the Johnston Canyon campground.

6 Mechanical erosion.

7 Chemical erosion dissolved the limestone and dolomite, producing the canyon's smooth sides.

8 A waterfall is created where water descends from a more resistant dolomite cap onto a softer layer of limestone.

9 A plunge pool.

10 The dipper.

11 Golden-mantled ground squirrels, chipmunks, pack rats, red squirrels, weasels.

12 Grizzly, black bear, lynx, coyote, elk, human beings.

13 Subalpine fir, Douglas fir, Englemann spruce, white spruce.

14 Maligne Canyon in Jasper National Park, Takakkaw Falls in Yoho National Park, and the Mistaya Canyon in Banff National Park.

15 Roughly on the border between Banff and Jasper National Parks. It provides a picture of what much of western Canada may have looked like during the Ice Age.

16 Natural landscapes are preserved and protected as part of Canada's heritage. They represent important components of our history and culture, which must be preserved for the benefit of generations to come.

Answers to science-process questions

Numbers following the answers refer to process skills listed in the inventory on Page 4.

1 (a) The varying amounts of suspended rock flour give each pool a different hue. (Skills: 2, 4)

(b) Rock flour is the remains of rock once pulverized by glacial ice. It indicates that glaciers were once present in the Johnston Creek area. (Skills: 7, 11)

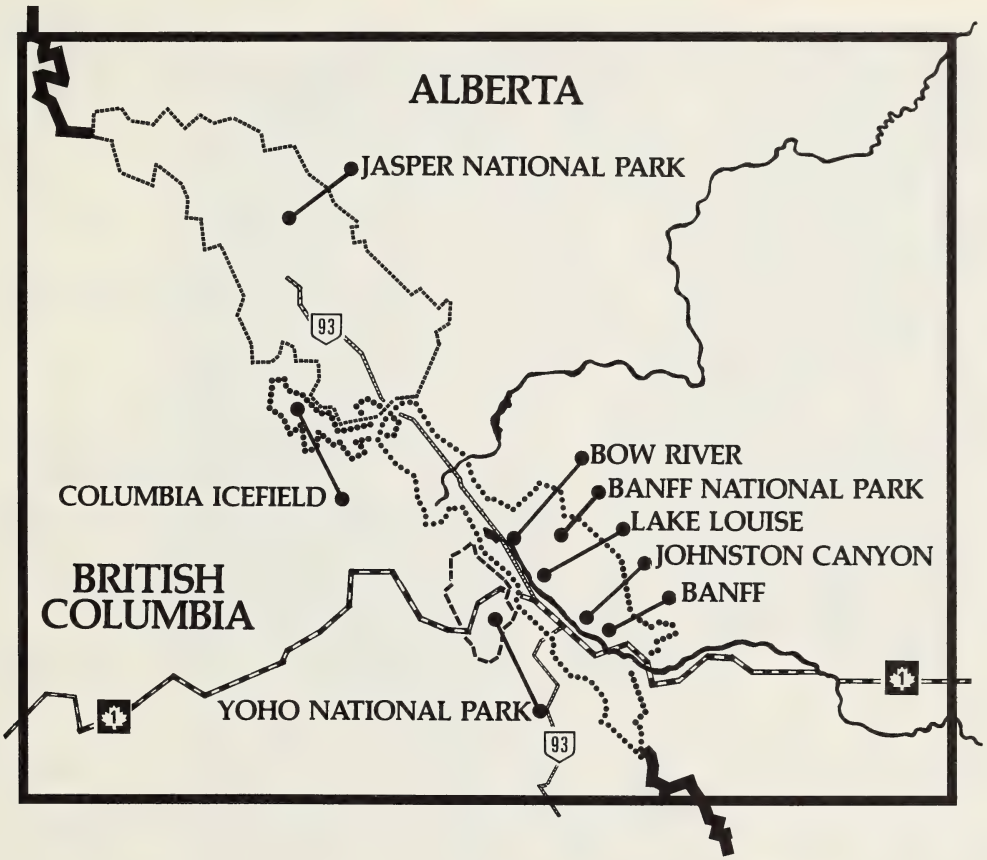
2 (a) Johnston Canyon has much to offer. It illustrates the awesome power of water to wear down mountains. (Skills: 4, 12)

(b) The newly constructed Bow Valley Parkway provides an alternate route for travellers to explore the area at their leisure. Along the paved, self-guiding trail, plaques and viewpoints describe the roles of water, rock and time in the formation and destruction of the Rocky Mountains. (Skills: 2, 5)

(c) The ability of Parks Canada to preserve and protect these special places depends upon the care taken by every person who visits Banff National Park. (Skills: 12, 14)

Answers to activity questions

1



2 One of the Ink Pots.

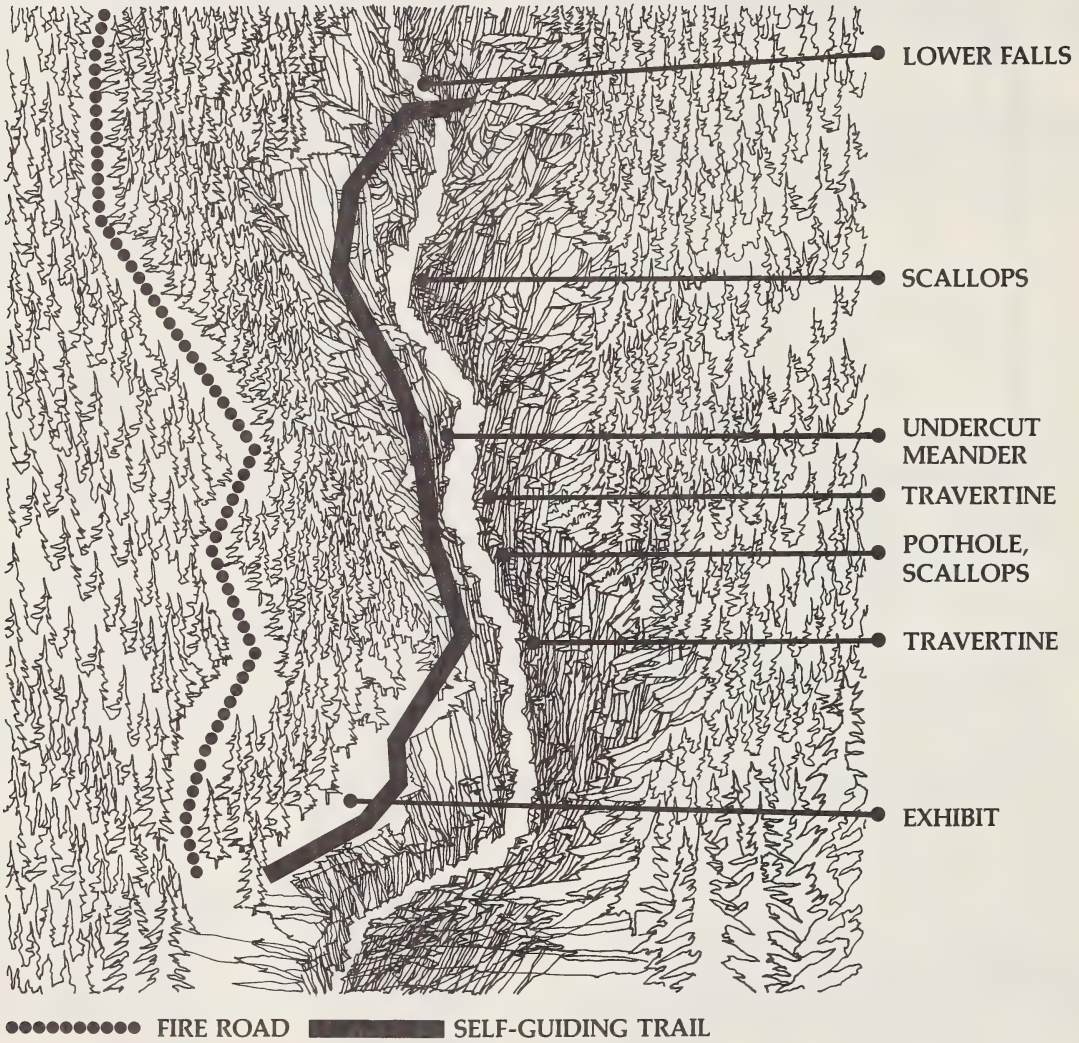
3 Great slabs of stone are pushed into the sky.
Water erodes the rock into a steep, V-shaped valley.
Glaciers grind the upper valley into a wide "U" shape.
Glacial meltwater sweep the canyons clean of till.
Water erodes a wide trough.
Water erodes a steep, "V"-shaped valley.
Deposition of debris forms an alluvial fan.

4

Mechanical Erosion	Chemical Erosion
– Shale Canyon	– Johnston Canyon
– pieces are dislodged by the force of rushing water	– water dissolves chemical elements in rock
– rough, ragged appearance.	– smooth, polished features.

Answers to activity questions

5



Answers to activity questions

6

DIAGRAM ONE

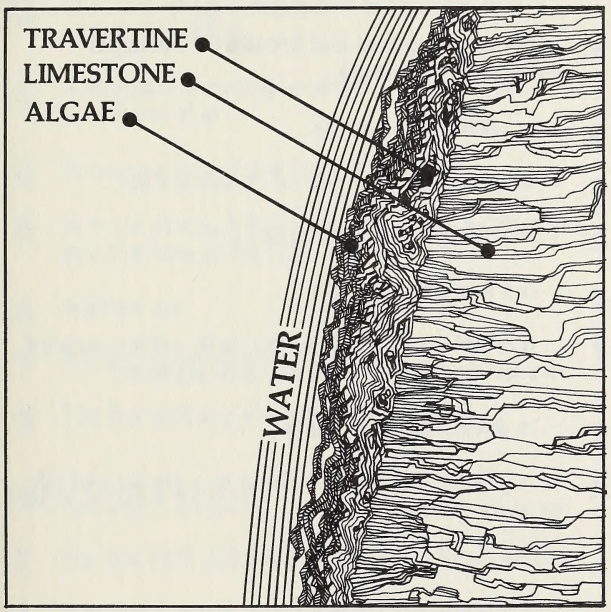
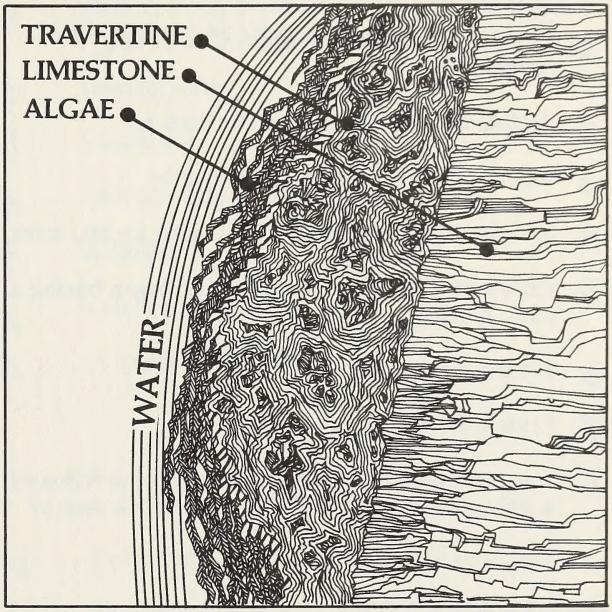


DIAGRAM TWO



7 The Columbia Icefield.

8 A plunge pool.

10 One of Canada's national parks.

12 Lodgepole pine, Douglas fir, aspen poplar, white spruce.

13
Pacific Rim
Mount Revelstoke
Glacier
Yoho
Kootenay
Waterton Lakes
Banff
Pukaskwa
Georgian Bay Islands
Point Pelee
St. Lawrence Islands
La Mauricie
Auyuittuq
Forillon
Kouchibouguac
Fundy
Prince Edward Island
Kejimkujik
Cape Breton Highlands
Gros Morne
Terra Nova
Grasslands
Jasper
Elk Island
Kluane
Nahanni
Wood Buffalo
Prince Albert
Riding Mountain

AND AT THE BACK. . .

. . .a review test covering all four programs in the series.

Match the wording in the left-hand column with the appropriate selection from the right-hand column. Use all the choices.

PROGRAM ONE

1	Millions of years ago, western Canada was covered by	a	. . .slowly deepened and broadened the upper valley into a U-shape.
2	Sediments were compressed into rock by	b	. . .a warm, shallow sea.
3	The Rocky Mountains were formed by	c	. . .high among the crags of Pulsatilla Pass.
4	Johnston Creek begins as rain, melting ice and snow	d	. . .the weight of many layers.
5	Drawn by the pull of gravity, water began tracing a path, carving	e	. . .an ancient creek bed.
6	A terminal moraine is	f	. . .powerful forces within the earth, which buckled the sediments up and thrust them skyward.
7	During the Ice Age, glaciers	g	. . .a deep, V-shaped valley.
8	Scientists believe that Johnston Creek once followed a different route because traces can still be seen of	h	. . .a pile of rock pushed ahead of a glacier and left upon its retreat.

PROGRAM TWO

1	Glacial till is	a	. . .calcium carbonate ($CaCO_3$).
2	Most of the glacial till was swept out of the valley by	b	. . .the rock and debris dropped at the point where the creek intersects with the valley.
3	Shale is composed of	c	. . .have been formed in different kinds of rock.
4	Water erodes shale by a process called	d	. . .mechanical erosion.
5	Johnston Canyon and Shale Canyon contrast sharply because they	e	. . .chemical erosion.
6	Johnston Canyon is composed of	f	. . .the rock and debris gathered up by a glacier and dumped on the valley floor upon its retreat.
7	Water erodes carbonate rock by a process called	g	. . .many fine layers of compressed silt.
8	Limestone is composed of	h	. . .meltwater released from glaciers.
9	Hydrochloric acid (HCL), when dropped on dolomite,	i	. . .limestone and dolomite.
10	The result of "micro" erosion is	j	. . .smooth, highly-polished stone.
11	The alluvial fan is	k	. . .causes little bubbling.

PROGRAM THREE

1 When water erodes limestone from beneath the harder surface of dolomite, the result is

2 The bowl-shaped depression at the base of a waterfall is called

3 A dry falls, standing west of the Upper Falls, is evidence that

4 Travertine drapes are formed by

5 In some places, Johnston Creek seems to disappear into the base of the cliff. This is called

6 Scallops are

7 An important agent of erosion is

8 The freeze/thaw process is most active

a ...smooth, polished depressions found in the exposed limestone floor.

b ...algae growing in areas that are rich in limestone and moistened by flowing water.

c ...running water.

d ...a waterfall.

e ...Johnston Creek has changed its course.

f ...in spring.

g ...a plunge pool.

h ...an undercut meander.

PROGRAM FOUR

1 The Ink Pots' colors are of different hues because

2 Johnston Canyon is just one area in the Rocky Mountains that tells the story of

3 Parks Canada has made the area accessible and attractive to the public by

4 The responsibility for the preservation and protection of these special areas depends on

a ...every person who visits Banff National Park.

b ...the amount of rock flour they contain varies.

c ...landscape sculpturing by water.

d ...building a paved, self-guiding trail with plaques and viewpoints describing the process of water erosion.

ANSWERS

PROGRAM 1 - ANSWERS
1. (b) 2. (d) 3. (f) 4. (c) 5. (g) 6. (h) 7. (a) 8. (e)

PROGRAM 2 - ANSWERS
1. (f) 2. (h) 3. (g) 4. (d) 5. (c) 6. (i) 7. (e) 8. (a) 9. (k) 10. (j) 11. (b)

PROGRAM 3 - ANSWERS
1. (d) 2. (g) 3. (e) 4. (b) 5. (h) 6. (a) 7. (c) 8. (f)

PROGRAM 4 - ANSWERS
1. (b) 2. (c) 3. (d) 4. (a)

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